MEGALITHIC SITES IN BRITAIN

BY

A. THOM

Chapter 9. The Calendar
Chapter 10. Lunar Declinations

OXFORD
AT THE CLARENDON PRESS
[1971]

CONTENTS

9

THE CALENDAR

(Thom 1971:107-117)

THE activities of early man were controlled just as ours are by the movements of the sun. So if he used a calendar it had to be related to the sun. As an approach to the subject it is perhaps best to forget for the moment about declinations, etc., observed at the sites and to consider what would be the ideal method of establishing and using a solar calendar assuming that it is to be based on observations of the sun made without instruments as we know them today. The Egyptians seem at one time to have controlled their calendar by observing what are called heliacal risings of certain bright stars, but this method is unsuited to northern countries with their long twilight. Moreover, the movement of the sun along the horizon is much greater in Britain than it is in Egypt and so more suitable as a calendar. It follows that we need have no hesitation in passing over the heliacal rising method and concentrating on a calendar controlled by observing the sun's position on the horizon.

We think naturally of dividing the year into four parts by the solstices and equinoxes. But these four times do not divide the year equally. They would do so only if the Earth's orbit were a circle. The modern definition of the equinox is the instant when the sun's declination is zero. But without instruments we cannot determine this instant. What we can do is to define the equinoxes as those two days which divide the year into two equal parts and on which the sun has the same declination, that is the same rising point. So we set up a mark *S* to show the position of the rising sun on a day in spring, the day being so chosen (by trial and error) that the mark serves also for a day in autumn half a year later. These two days of the year are thus fixed by the mark *S* for all future years.

It will be shown that the dates so determined are near the equinoxes but not exactly at the time when the sun's declination is zero. They are the times when the declination is about +0°·5. This is, for our investigation, fortunate because if, in the field, we find marks for declinations definitely between 0 and 1° we know we are thinking along the right lines.

Now suppose we wish to divide the year into eight and set up a mark showing the rising point one-eighth of a year after our vernal equinox, that is May Day. Will this mark also serve for Lammas if we define Lammas as being the day one-eighth of a year before the autumnal equinox? To give precision to this question it is necessary to define what is meant by one-eighth of a year (in days) and then make the necessary calculations from our knowledge of the Earth's orbit at the time in which we are interested, say 2000 to 1600 B.C.

Let us anticipate and say that in Megalithic remains we do find definite evidence of this kind of division of the year. We saw that when Megalithic man subdivided his units of length he used halves, quarters, and eighths so we need not be surprised to find his year similarly divided. But we also saw that he was capable of measuring long distances counting in tens. He would certainly also count days, otherwise how did he divide the year into two ? His obsession with numbers may have led him to produce a calendar which would be numerically correct just as he was led to attempt to produce circles and ellipses which were rational in all their dimensions. Following the method used above we shall try how nearly we can get to an ideal calendar using the methods available to these people, but first we must clear up one or two points.

The reader may have wondered what we meant when we spoke above of half a year, since the tropical year (equinox to equinox) consists of $365\frac{1}{4}$ days, and half a year is $182\frac{5}{8}$ days. Having set up our mark *S* and seen the sun rise exactly on it on a day in the spring we may have arranged matters so that the sun rises again on the mark after 182 days or after 183 days but certainly not after $182\frac{5}{8}$ days. That would be in the afternoon.

Starting at the declination corresponding to either the 182- or the 183-day arrangement it takes the sun $365\frac{1}{4}$ days to complete a cycle and again come back to that declination. So when it rises after 365 days the declination will not have attained its initial value but will be about $0^{\circ}{\cdot}1$ too small. We have seen that if the mark is a good natural foresight it is capable of showing up a very much smaller error than this. In successive years the error will grow until after four years the sun will be late by a whole day and so will be exactly on the mark the following morning.

From the time of Julius Caesar our calendar has inserted that extra day every fourth year. Was the necessity to introduce a leap year known to Megalithic man ? We shall see that it is certain that he used a solar method of keeping a calendar and that it depended on horizon marks subdividing the year. But each mark must have been established by counting days from a zero date in the year, and each mark served to define two different epochs, one in the spring half of the year and one in the autumn half. It not only took years of work to establish these marks but many more years to transport and erect the huge permanent backsights. In the interval the marks would have got so badly out as to be useless if an intercalary day were not inserted.

It is true that these people, having set up the mark, might have stopped keeping a tally of days, simply leaving the marks to give the indications. But the Megalithic culture was widespread and communication essentially slow. To transfer the 'date' from one end of the system to the other meant that the messengers must have counted days as they travelled and having arrived at an isolated community the counting had to go on until a year with suitable weather allowed the marks to be set up. The alternative is to assume that each community began independently the arduous task of establishing its own calendar epochs. This is indeed possible, but when we find indications of the same declinations in Cumberland, Lewis, Wales, and Caithness we must consider the possibility that the calendar dates throughout this wide area were in phase.

The sixteen-month calendar

As the author collected more and more reliable lines from the sites certain groups of declinations began gradually to appear in positions on the histogram which were difficult to explain. These were at or near -22°, -8°, +9°, and +22°. The group at +9° might be ascribed to Spica at 1700 B.C., but there were no convenient stars to explain the others. If they are solar then we seek the times of year at which the sun had these declinations. Accepting these dates, we find that with the fully established solstices, equinoxes, May/Lammas, and Martinmas/Candlemas days the year is divided into sixteen equal parts. The data in the field on which these subdivisions rest is sufficiently convincing and reliable to make it necessary to go into the matter in detail. We must calculate the sun's declination throughout the year. The necessary formulae are given on p. 24. The constants defining the Earth's orbit will be taken for 1800 B.C. as being representative of the years from say 2000 to 1600 B.C. The values are:

Obliquity of the ecliptic	$= \epsilon = 23^\circ{\cdot}906$,
Longitude of sun at perigee	$= \pi = 218^\circ{\cdot}067$,
Eccentricity of orbit	$= e = 0.0181$.

Having used these to calculate the sun's declinations and plotted these declinations we obtain a curve like that shown in Fig. 9.1. This attains a maximum of $+23^\circ{\cdot}91$ at the summer solstice and a minimum of $-23^\circ{\cdot}91$ at the winter solstice. As already explained, the two lobes are not of equal length so we take three points S, A, and S' such that $SA = AS'$ and find that the declination at these points is $+0^\circ.51$. We have seen, however, that we cannot divide the year for our present purpose into two equal parts but must take SA as being either 182 days or 183. In Thom, 1966, 182 was used. Here we shall take 183. Obviously to get 183 days (instead of $182\frac{5}{8}$) the line $S_1\ A_1$ must be lowered slightly.

It is now necessary to find the ideal declinations for the other calendar epochs. On Fig. 9.1 we require to find six declinations, represented by three horizontal dotted lines in the positive lobe and three in the negative lobe. Each horizontal line gives a date at each end and the problem is to arrange matters so that these dates with the equinoxes and solstices divide the year as nearly as possible into sixteen equal parts, which we shall call 'months'. The solution referred to above restricted a month to 22 or 23 days. The criterion of a good solution is that the declinations must pair, that is the day in the autumn should have the same declination as the corresponding day in the spring. The solution obtained by the 22/23-day month did not give very good pairing. Accordingly, it was decided to try to find from the observed declinations what solution Megalithic man had obtained.

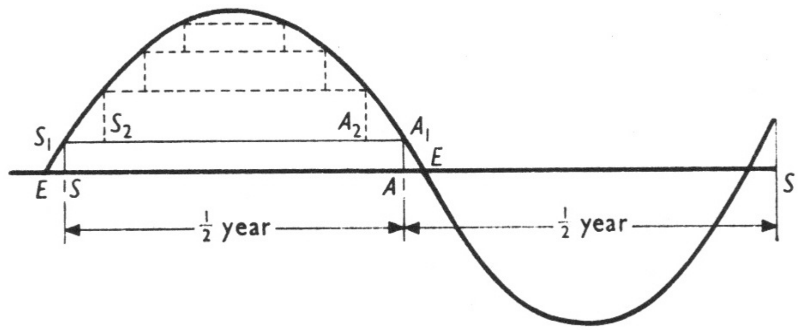

FIG. 9.1. Sun's declination throughout the year. *E*, *E*, true equinoxes. *A* is mid-way between *S* and *S*. *S* and *A* are Megalithic equinoxes.

Weighted means for the six necessary declinations (seven with the equinoctial value) were formed from the observed values in Table 8.1. Using these the corresponding dates were read off (two for each mean declination) from a large-scale plot of the theoretical declination curve (Fig. 9.1).

It is remarkable that this procedure led to a much better solution than had previously been found. The arrangement of the 'months' is shown in Table 9.1, from which it will

Table 9.1. *Calendar declinations*

Epoch Number	Days in 'month'	Epoch		δ_R decl. at sunrise	δ_S decl. at sunset	Possible decl. range
		Nominal	Days elapsed at sunrise (t)			
0	23	0	−0·4	+ 0·37	+ 0·56	±0·19
1	23	23	22·56	+ 9·04	+ 9·24	0·17
2	24	46	45·53	+16·55	+16·72	0·14
3	23	70	69·51	+22·03	+22·13	0·07
4	23	93	92·50	+23·91	..	0·00
5	23	116	115·51	+22·09	+21·99	0·07
6	23	139	138·53	+16·80	+16·62	0·14
7	22	161	160·56	+ 9·31	+ 9·09	0·17
8	22	183	182·60	+ 0·51	+ 0·33	0·19
9	22	205	204·62	− 8·40	− 8·57	0·18
10	22	227	226·67	−16·24	−16·35	0·14
11	23	250	249·69	−21·92	−21·98	0·07
12	23	273	272·70	−23·91	..	..
13	23	296	295·70	−21·82	−21·72	0·08
14	23	319	318·68	−16·30	−16·15	0·14
15	23	342	341·64	− 8·52	− 8·37	0·19
16	..	365	364·60	+ 0·28	+ 0·47	..

Mean values at both sunrise and sunset are identical and are +0°·44, +9°·16, +16°·67 +22°·06, −8°·46, −16°·26, −21°·86.

be seen that there are 4 months with 22 days, 11 with 23, and 1 with 24. Column 3 shows the number of days from the zero day, the vernal equinox. The calculation of the exact declination at the various epochs is connected with the question of how the intercalary day was inserted. Let us take it that an extra day was given to the years $T-2$, $T+2$, $T+6$, etc. Ideally the azimuthal lines should be erected to suit the year T. They will then be correct also for the years $T+4$, $T+8$, etc., and they will show the greatest errors in the years $T+2$, $T+6$, etc. So we have to search for the best solution, ascribe this to the year T, and calculate the errors for the years $T+2$, $T+6$, etc.

Having accepted the arrangement of months shown in column 2 them is still a disposable constant, namely, the exact instant of zero time for calculation purposes. This must be chosen to give the best possible 'pairing' of the declinations.

Put δ_o = declination at epoch 0,
δ_1 = ,, ,, 1,
etc.

Then put

$$e_1 = \delta_o - \delta_8,$$
$$e_2 = \delta_1 - \delta_7,$$

and so on up to e_7, forming similar values for setting times.

The ideal value of zero time t_o is that which makes the root mean square (e_M) value of the fourteen values of e a minimum. Two values of t_o were tried, namely $t_o = 0$ and $t_o = -0{\cdot}4$ days. It is the solution corresponding to the latter value which is given in Table 9.1, where we accordingly write $-0{\cdot}4$ as the time of sunrise on the zero epoch. After 23 days the sun rises about 0·04 days earlier in the morning (and sets 0·04 days later at night). So the interval to the next sunrise is not 23 days but 22·96, and the time of sunrise is 22·96 added to $-0{\cdot}4$ or 22·56 days. In this way column 4 is built up.

We now convert these values to 'longitude of dynamic mean sun' (l) by multiplying by $360/365\frac{1}{4}$ and then using the formulae on p. 24 we can calculate the sun's declination at sunrise on the first day of each month. A similar calculation is made for sunset on the same days. The results are given in columns 5 and 6. Finally column 7 contains the changes which take place in two years and so shows the maximum error in the leap-year cycle of four years. We must now make sure that we have used the best possible value for t_o. To do this we calculate the values of ϵ_1, ϵ_2, etc. for rising and setting. Summing the squares of these shows a mean value of about $0^\circ{\cdot}18$, a highly satisfactory result.

Repeating the calculation for $t_o = 0$ shows a much higher mean error of about $0^\circ{\cdot}30$.

There is now enough information to enable us to write each value of *e* as

$$\epsilon = a + bt_o$$

where the numerical values of *a* and *b* are found by comparing the two solutions. It follows that

$$\sum \varepsilon^2 = \sum a^2 + 2t_o \sum ab + t_0^2 \sum b^2$$

Differentiating and equating to zero shows that this is a minimum when

$$t_o = -\sum ab / \sum b^2$$

Making the relatively short calculation indicated we find $t_o = -0{\cdot}47$. Fortunately this is so near to the value used (- 0.40) in Table 9.1 that there is no need to repeat the calculation. We shall accordingly accept the values in that table as the best possible arrangement. Since it is impossible to obtain perfect pairing we form the mean declination for each pair. We find that these mean values are practically identical for the sunrise and sunset declinations. This comes about because for each pair the rate of fall of the declination in the autumn is nearly the same as the rate of rise in the spring. These means, which are the ideal values we must expect if Megalithic man's calendar was identical with that set out in Table 9.1, will be found below the table.

For those who do not want to follow through the above reasoning the results can be stated thus.

If Megalithic man wanted

(1) a calendar of sixteen nearly equal divisions of the year,
(2) marks erected on the horizon to show the rising and setting positions of the sun at the sixteen necessary epochs,
(3) each mark to serve for two of these epochs, one in the spring half of the year and one in the autumn half,

then there was no better method available than to set the marks for the declinations shown below Table 9.1.

Instead of obtaining the necessary declinations by trial calculations we imagine Megalithic man experimenting for years with foresights for the rising and setting sun. We do not know how sophisticated his calendar was, but the interesting thing is that he obtained declinations very close to those we have obtained as the ideal. The comparison can be seen roughly on Fig. 8.1 where the sun's declination at the various epochs is shown by a circle, but the scale is too small to show detail. Accordingly the parts of the histogram near and around the germane declinations have been drawn to a larger scale in Fig. 9.2. The conventions used for showing the observed declinations are generally similar to those of the main histogram, but relative to the declination scale the gaussians are much smaller. Look first at the observed declinations near the solstices. The circle drawn to represent the sun is of such a size as to show the spread of declination produced

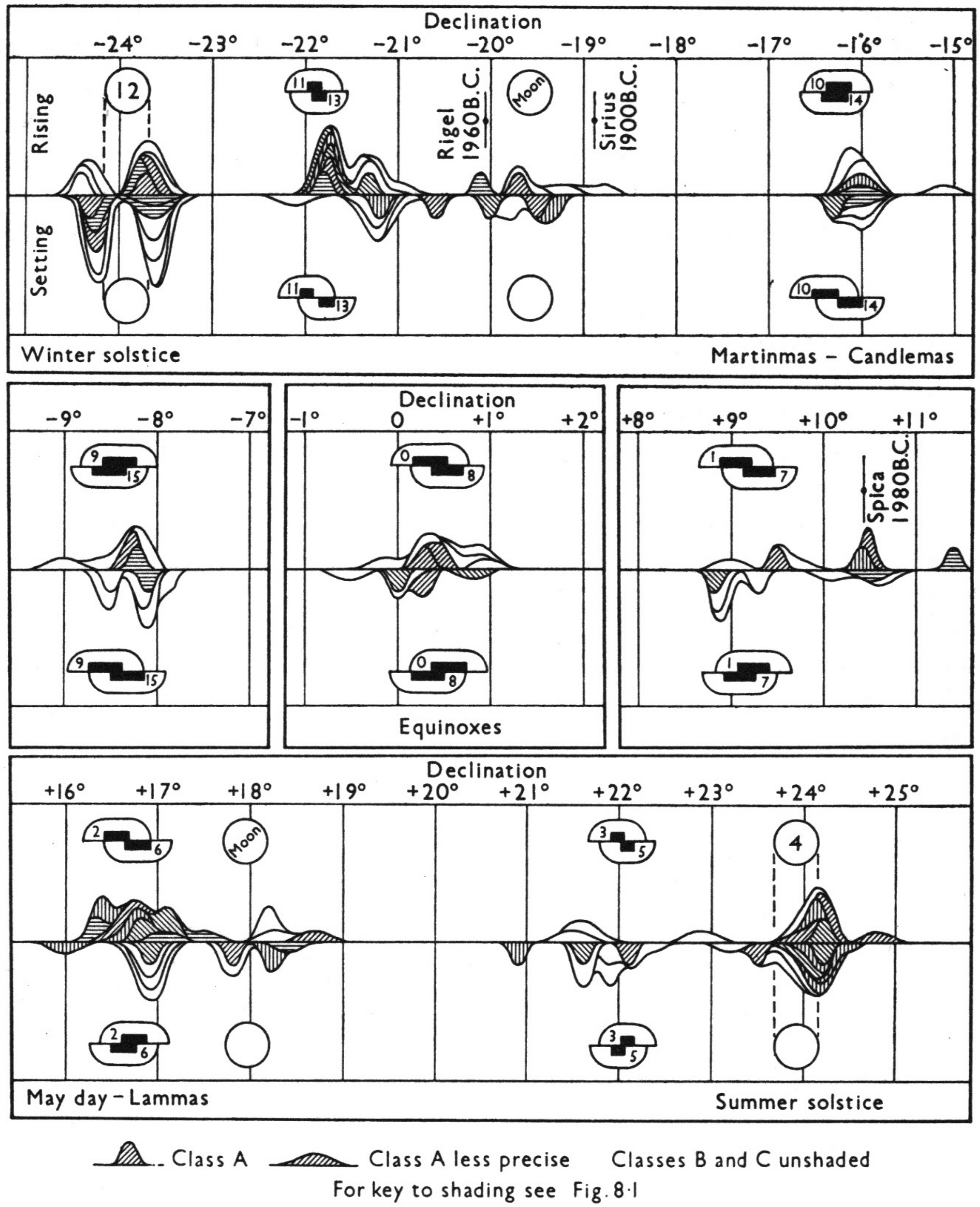

FIG. 9.2. Calendar declinations.

by the sun's diameter. A majority of the observed declinations lie to the right of the disk at both solstices, showing that the upper limb was favoured. That is, the foresight was usually chosen to show the first appearance of the upper edge in the morning or the last at setting. There would appear, however, to be one or two reliable lines showing the sun as it left the horizon in the morning or as it touched it in the evening.

For the other fourteen epochs the declinations calculated for the ideal calendar are shown by little black rectangles, the width of each rectangle showing the unavoidable spread of the declination in the four years of the leap-year cycle. The two rectangles at the top of each section show the rising declinations at the two paired epochs, the displacement of the one relative to the other being the amount by which the solution falls short of perfect pairing, the e of the analysis. All this is for the sun's centre: the limits for the upper and lower limb are shown by the ends of the curve drawn to embrace each rectangle. The calculated setting declinations are shown in the same convention at the bottom of the figures. As already explained, the mean rising and setting declinations are equal, but the spread may be very different.

In comparing with the observed declinations shown by the gaussians it must be remembered that many of these, for one reason or another, may be uncertain by perhaps ±0·25, rather more than is indicated by the gaussians. In spite of this the agreement is good, but when the comparison is restricted to those lines which can be considered to be precise we get excellent confirmation. This is brought out in Table 9.2, which contains all those lines where the declination is considered to be known to ±0·1. The difference between using the upper and the lower limb (on a level horizon) is shown by the two values of the expected declination (δ_E) shown at the head of each column. These values are the means shown below Table 9.1 with ±0·22 added. For indicated foresights with a mountain slope nearly parallel to the path of the setting sun the range would be rather greater (±0·27), being in fact the sun's semidiameter.

Table 9.2

Epochs 0 and 8		Epochs 1 and 7		Epochs 2 and 6		Epochs 3 and 5	
δ_E	+0°·22 +0·66	δ_E	+8°·94 +9·38	δ_E	+16°·45 +16·89	δ_E	+21°·84 +22·28
G 8/8	+0°·5	H 3/2	+8°·8	G 4/14	+16°·8	A 2/5	+21°·9
H 2/2	+0·0	N 2/1	+9·1	H 4/4	+16·9	A 3/18	+21·6
N 2/1	+0·3	G 6/2	+8·9	N 2/1	+16·6	H 5/1	+21·9
				L 1/7	+16·7	W 11/5	+21·7
				W 5/1	+16·9		
Epochs 9 and 15		**Epochs 10 and 14**		**Epochs 11 and 13**			
δ_E	−8°·68 −8·24	δ_E	−16°·48 −16·04	δ_E	−22°·08 −21·64		
A 2/8	−8°·2	A 8/1	−16°·3	H 3/11	−21°·7		
A 6/5	−8·1	M 4/2	−16·2	N 1/15	−22·2		
L 1/1	−8·1			N 1/15	−21·7		
N 1/15	−8·3						

It will be seen that we have here conclusive proof that the erectors succeeded to a remarkable degree in getting a reliable calendar of the kind we have developed on theoretical grounds.

Later, brief notes will be given of the reliable calendar sites in Britain, but we may here draw attention to an interesting site near Watten in Caithness (N 1/15). The lines from this site are not included in the histograms or in the main table but they have been included in Table 9.2, above. All that is left at this site is a 6-ft standing stone, a large fallen stone, and an artificial depression, but on looking to the south-west one sees a number of mountain peaks projecting behind an almost level middle distance (Fig. 9.3).

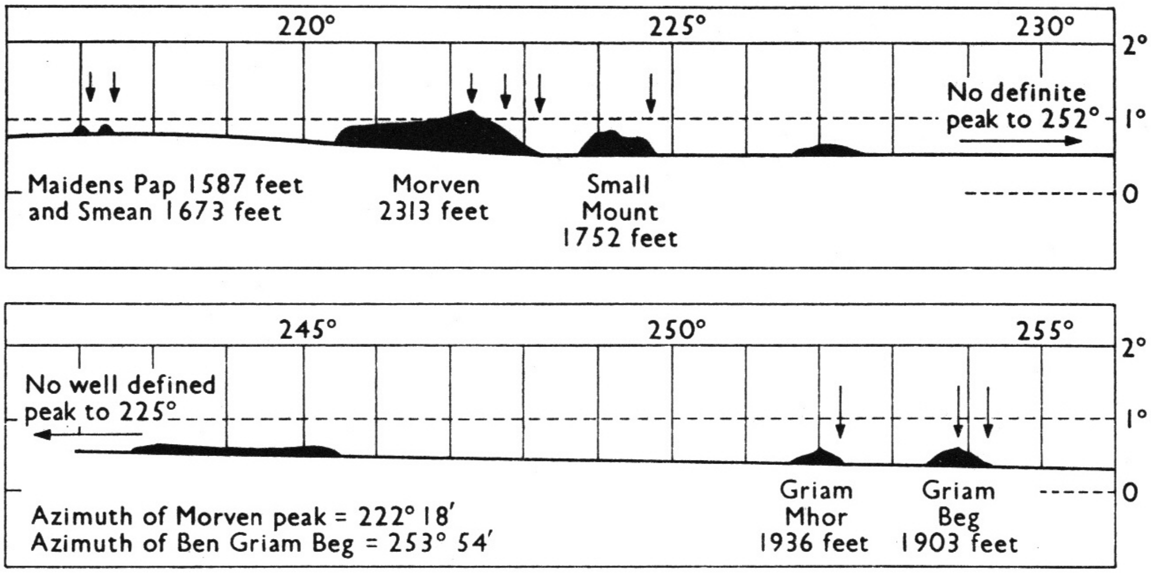

Fig. 9.3. Horizon to south-west from stones near Watten, ND 223516. Arrows indicate measured points.

Four of these are well defined with the fight-hand slope giving the necessary conditions for a perfect foresight. The author was so struck by the possibilities that these were carefully measured up and the azimuths of two calculated geodetically from the Ordnance Survey. The particulars for the foot of the slopes are given below.

Peak	Az.	*h*	Decl.	Expected decl.
Morven	222·72	0·87	−22·20	−22·13 or −21·59
Small Mount	224·75	0·53	−21·74	
Ben Griam Beg	254·25	0·38	− 8·28	−8·73 or −8·19

In a position like this with distant peaks seen from relatively level ground it is of course possible to choose a position from which two of the peaks will have the required declinations, but it is very unlikely that a third peak will be in a position to give a third declination. Morven and Small Mount suit the lower and upper limbs of the sun, while Ben Griam Beg is only wrong by 0°·09 for the upper limb. Smean is slightly too far to the left for the solstitial sun and would necessitate an observing position a short distance to the east. Nevertheless it seems likely that this is a genuine calendar site.

A possible further subdivision

The improbability that the year was further subdivided into 32 parts of 11 or 12 days is considerably lessened by the accuracy with which certain otherwise unexplained lines support such a subdivision. As some of the lines are Class A it may be desirable to give the evidence and leave it there for future work to decide the matter. As before, guidance in choosing the epochs was obtained partly from the observed declinations and partly from pairing. Ultimately almost complete pairing was obtained with epochs which, it will be seen (Table 9.3, below), retain the eleven- or twelve-day interval, which would thus very likely apply to the whole year although the evidence at present only exists for twenty-four epochs. The calculated declinations for the four necessary extra pairs are given in the table.

Table 9.3

Nominal day	Decl.	Nominal day	Decl.	Mean of pair
12	+ 4·97	172	+ 5·00	+ 4·98
35	+13·16	150	+13·29	+13·22
194	− 4·00	354	− 3·98	− 3·99
216	−12·54	330	−12·78	−12·66

It will be seen that the pairing is very good. The next table (Table 9.4) contains the observed lines as extracted from the main table. Since these lines all have level horizons the comparisons should be made with the mean values from the above table ±0°·22 .

Table 9.4

Site		Decl.	Expected decl.
L 1/7	Long Meg	+ 5·2	4·76
W 8/1	Rhosygelynnen	+ 4·9	and 5·20
H 3/1	Cladh Maolrithe	+13·2	13·00
W 8/3	Four Stones	+13·9	and 13·44
S 6/1	Rollright	− 3·8	−4·21
W 6/1	Rhos y Beddau	− 3·7	and −3·77
W 8/1	Rhosygelynnen	− 3·3	
P 2/17	Dowally	− 3·9	
B 1/18	Ardlair	−13·4	−12·88
W 5/2	Twyfos	−12·7	and −12·44
P 1/1	Muthill	−12·7	

The agreement shown with the expected declinations is so good that the possibility that the year was divided into periods of eleven and twelve days must be examined further as data become available.

It is proposed here to call the extra dates suggested above 'intermediate calendar dates'.

The exact time of the solstices

Looking at the formulae used for the calculation of the declination we see that the declination was a maximum when $\odot$, the sun's longitude, was $\pi/2$. From the relation between $\odot$ and l we find that *l* was then 92°·08, which is equivalent to 93·4 days. From Table 9.1 we see that this was 0·9 days after sunrise on the fourth epoch. Similarly the winter solstice was 0·7 days after sunrise on the twelfth epoch. Twenty-four hours after the solstice the declination has only fallen by some 12 seconds of arc, which would hardly be detectable. How then does it come about that the solstices were known so accurately ? The explanation lies in that the epochs on either side of the solstice were arranged to be the same number of days from the solstice, namely twenty-three days for both summer and winter. This is still one more example of the care with which the calendar was arranged. At a site like Ballochroy (see p. 151) they could satisfy themselves that the declination really was a maximum even though the change was not perceptible for a day or two.

***

Chapter 9: The Calendar, A. Thom, *Megalithic Sites in Britain*,
Clarendon Press, Oxford, 1971:107 - 117.

10

INDICATIONS OF LUNAR DECLINATIONS

(Thom 1971:118-121)

ONE is inclined to think of the moon as occupying a great range of positions in the sky and so the tendency is to dismiss the moon with the thought that almost any line will show its position on the horizon sooner or later. But we have seen on p. 21 that there are four limiting declinations and it is for these that we must look. We shall see that these positions were considered important and were marked very definitely.

The obliquity of the ecliptic at 1800 B.C. was 23°·91 and the mean value of the inclination of the moon's orbit 5°·15. So at the solstices the four extreme values of the full moon's declination were

$$\pm(23°{\cdot}91+5°{\cdot}15), \quad \text{i.e. } \pm 29°{\cdot}06$$

and

$$\pm(23°{\cdot}91-5°{\cdot}15), \quad \text{i.e. } \pm 18°{\cdot}76.$$

To compare an observed azimuthal line with one or other of these values the direct method would be to correct the altitude of the horizon for refraction and parallax before it was used to compute the declination. For our present purpose it is, however, easier and sufficiently accurate to reverse the process and to compute the effects of parallax on the declinations. These effects can then be applied to the four above values. The declinations so found might be called the expected declinations (δ_e) and are ready to be compared directly with those given in Table 8.1, which were of course found without any correction for parallax.

Let Δh be the moon's horizontal parallax. Since the altitudes are all small the effect of this on a computed declination is

$$\Delta\delta = \Delta h \times d\delta/dh.$$

Δh is about 0°.95 and in these latitudes $d\delta/dh$ has a value of about 0·94 when δ is 29° and about 0·87 when δ is 19°. So we obtain the following expected declinations:

at the winter solstice

$$\delta_e = 29°{\cdot}06 - 0°{\cdot}95 \times 0{\cdot}94, \quad \text{i.e. } +28°{\cdot}17,$$

and

$$\delta_e = 18°{\cdot}76 - 0°{\cdot}95 \times 0{\cdot}87, \quad \text{i.e. } +17°{\cdot}94;$$

at the summer solstice

$$\delta_e = -29°{\cdot}06 - 0°{\cdot}95 \times 0{\cdot}94, \quad \text{i.e. } -29°{\cdot}95,$$

and

$$\delta_e = -18°{\cdot}76 - 0°{\cdot}95 \times 0{\cdot}87, \quad \text{i.e. } -19°{\cdot}58.$$

Table 10.1. *Observed declinations assumed to be those of the full moon in its extreme positions at the solstices.*
δ = observed declination, δ_e = expected declination, $\beta = \delta - \delta_e$

Midsummer lowest $\delta_e = -29{\cdot}95$			Midsummer highest $\delta_e = -19{\cdot}58$			Midwinter lowest $\delta_e = +17{\cdot}94$			Midwinter highest $\delta_e = +28{\cdot}17$		
Site	δ	β	Site	δ	β	Site	δ	β	Site	δ	β
A 2/8	−30·3	−0·35	A 2/8	−20·1	−0·52	B 2/4	+18·4	+0·46	A 2/12	+28·2	+0·03
A 2/19	−29·9	+0·05	A 6/6	−20·0	−0·42	L 1/6	+17·8	−0·14	A 10/6	+27·9 *P*	−0·27
A 4/1	−29·7	+0·25	B 3/5	−19·8	−0·22	L 1/6	+18·3	+0·36	G 4/2	+28·5±	+0·33±
A 6/4	−30·4 *P*	−0·45	B 7/3	−19·5	+0·08	M 2/14	+18·2	+0·26	H 1/14	+28·5 *P*	+0·33
G 3/3	−30·4	−0·45	G 9/13	−19·7	−0·12	P 1/1	+18·7	+0·76	L 1/6	+27·5	−0·67
H 1/1	−30·2 *P*	−0·25	G 3/3	−19·6	−0·02	P 1/8	+18·2 *P*	+0·26	M 2/8	+28·6	+0·43
H 3/6	−29·8	+0·15	H 1/2	−18·8	+0·78	S 1/2	+17·5	−0·44	S 5/2	+28·4	+0·23
L 1/1	−29·8	+0·15	H 1/15	−19·3	+0·28	W 9/7	+17·8 *P*	−0·14			
L 1/11	−30·2±	−0·25	H 3/3	−19·2	+0·38						
L 6/1	−30·7	−0·75									
M 4/2	−30·4	−0·45									
N 1/13	−29·7	+0·25									
P 3/1	−29·9	+0·05									

The six Class A lines marked *P* are considered to be reasonably precise.
Any values of β greater than 1°·0 (numerically) are excluded, but for midwinter lowest the limit of 0°·8 was used to avoid confusion with the May Day/Lammas lines.

These are the four declinations which are marked on the main histogram (Fig. 8.1) by four shaded circles. It will be seen that they all carry groups of observed lines, the concentration at - 30° being particularly large. Two of these declinations also come into the range covered by the histogram of the calendar lines (Fig. 9.2), where it will be seen

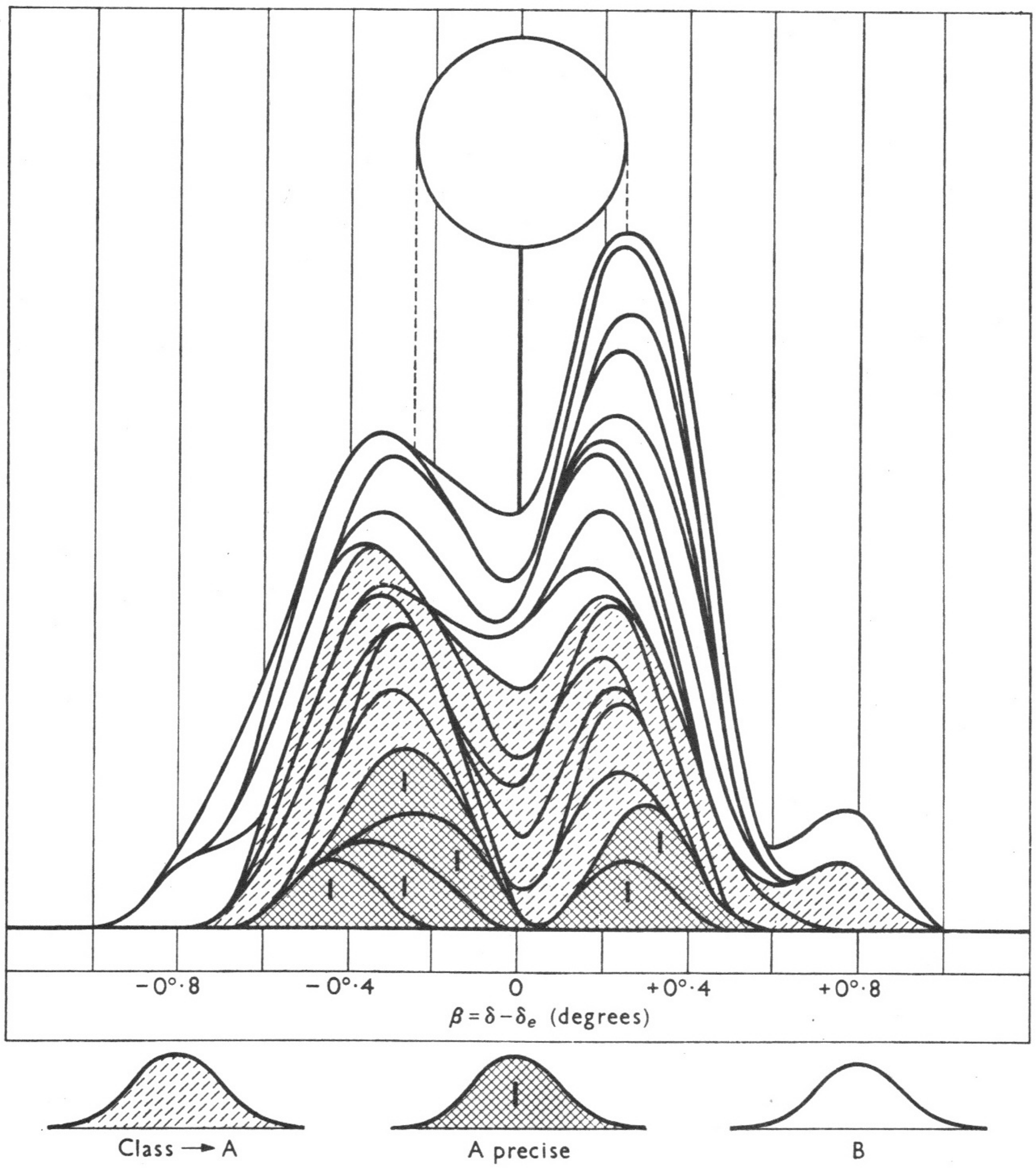

FIG. 10.1. Distribution of suspected lunar lines plotted as observed declination minus expected declination.

how the gaussians tend to pile over the upper or lower limbs. To look into this question of the limbs it was decided to combine all four cases. This can be done conveniently by finding by how much every observed declination differs from the expected and then plotting these as a histogram.

In Table 10.1 will be found all declinations which lie within 1° of the expected values. In Fig. 9.2 it will be seen that one of these expected lunar lines comes near one of the expected solar lines, necessitating here a limit of 0°·8. Otherwise nothing has been excluded and the declinations are just as they were computed from the field material.

The deviations from the expected values are tabulated as $\beta = \delta - \delta_e$. A histogram of these values will be found in Fig. 10.1. The remarkable way in which the gaussians form a peak for each limb of the moon will be noticed. The Class A lines are shown shaded and it will be seen that they alone produce the double peak, rather more lines going to the lower limb. There are six lines in the table (marked *P*) which are considered to give the declination with a precision better than ±0°·1. The gaussians for these lines are shown hatched in both directions, bringing out clearly how closely these reliable lines cluster about one limb or the other.

There are several obvious ways in which we can make a very rough estimate of the probability that these declinations would accidentally group themselves as they do if they were entirely random. The probability level comes out so very low on any reasonable way of estimating that it can be accepted as certain that these lines were set out intentionally to mark these declinations. As no other explanation can be found for the declinations involved we must accept that they have a lunar significance.

As explained in Chapter 3 there is a periodic term of amplitude 9' or 0°·15 superimposed on the moon's declination and the question arises as to whether the marks were set up for the mean maximum declination or for the absolute maximum. Many of the lines discussed in this chapter are incapable of discriminating, but there are a number of sites where not only can the difference be seen but it can be measured on the mountain tops. Unfortunately, not all of these lines contain unequivocal indicators pointing to the exact spot or spots. Accordingly, to be logical it is necessary to establish that lunar lines were used before going on to consider the evidence showing that Megalithic man actually observed and recorded the 9' oscillation. That has been the object of this chapter.

At the four or five sites where there is a possibility of a precision of ±1' it will appear that it was not the mean maximum which was indicated, but that the top and bottom of the little wave shown in Fig. 3.5 (c) were both exactly recorded. But these sites need to be dealt with individually and they will be taken in their own place in the description of sites in Chapters 11 and 12.

In the meantime it may be said that Megalithic man's interest in the 9' oscillation probably arose from the fact that eclipses can happen only when the Moon's declination is near the top of one of these waves.

***

Chapter 10: Indications of Lunar Declinations, A. Thom, *Megalithic Sites in Britain*, Clarendon Press, Oxford, 1971:118-121.

Further selections from *Megalithic Sites in Britain*: